N72-23049

CASE FILE COPY

EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TESTS
OF
EAGLE–PICHER 100 AMPERE–HOUR
NICKEL–CADMIUM CELLS
WITH AUXILIARY ELECTRODES

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT S-23404-G

QUALITY EVALUATION LABORATORY

NAD CRANE, INDIANA

NAVAL AMMUNITION DEPOT
QUALITY EVALUATION AND ENGINEERING LABORATORY DEPARTMENT
CRANE, INDIANA 47522

EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
EAGLE-PICHER
100 AMPERE-HOUR
NICKEL-CADMIUM CELLS
WITH AUXILIARY ELECTRODES

QEEL/C 72-126 10 MARCH 1972

PREPARED BY

D. E. Christy
D. E. CHRISTY

PREPARED UNDER THE DIRECTION OF

DEMains
D. E. MAINS
Manager, Space Satellite
Cell Programs Branch

APPROVED BY

H. L. Forston
H. L. FORSTON
By direction

Enclosure (1)

REPORT BRIEF
EAGLE-PICHER COMPANY
100 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
WITH AUXILIARY ELECTRODES

Ref: (a) NASA P. O. S-23404-G
(b) Acceptance Test Procedure for Nickel-Cadmium Cells: NAD 3052-TP304 Rev A, 14 May 1970

I. TEST ASSIGNMENT BRIEF

A. The purpose of this acceptance test program is to insure that all cells put into the life cycle program are of high quality by the removal of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open circuit voltage above 1.150 volts after the cell short test.

B. Five cells were purchased by National Aeronautics and Space Administration, Goddard Space Flight Center, from Eagle-Picher Company, Joplin, Missouri. The cells were rated at 100 ampere-hours and equipped with auxiliary electrodes. Testing of these cells was funded in accordance with reference (a).

II. SUMMARY OF RESULTS

A. The capacity of the 24 cells ranged from 103.5 to 119.0 ah. All the cells exceeded the rated capacity on all three capacity checks.

B. All cells recovered above the 1.150-volt requirement after the cell short test.

C. These cells cannot be overcharged at the c/10 rate without exceeding 1.500 volts after approximately 12 to 13 hours of charge.

D. A special resistance test was conducted on the auxiliary electrodes of these cells. This test was designed to establish the resistance value necessary which would provide maximum signal power across the auxiliary electrode. The resistance value thus established was 10 ohms.

E. One cell (S/N 3) revealed a definite leak at the negative terminal.

III. RECOMMENDATIONS

A. This activity does not recommend these 100 ampere-hour cells for further testing or for use in space. This recommendation is based on continuous difficulties encountered during overcharge requirements.

RESULTS OF ACCEPTANCE TEST OF 100 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS WITH AUXILIARY ELECTRODES MANUFACTURED BY EAGLE-PICHER COMPANY

I. INTRODUCTION

A. On 12 February 1972 acceptance tests were begun on five cells manufactured by the Eagle-Picher Company, Joplin, Missouri. These tests were completed 25 February 1972.

II. TEST CONDITIONS AND PROCEDURE

A. These cells were operated within a cold plate fixture designed by Goddard Space Flight Center. The temperature of this plate was maintained at 20° C, as specified by Goddard, by using a temperature-controlled water bath to circulate water through the fixture.

1. Phenolphthalein Leak Test.

2. Three Capacity Checks.

3. Cell Short Test.

4. Phenolphthalein Leak Test.

5. Overcharge Tests, c/20 and c/10 Rates.

6. Special Resistance Test of Auxiliary electrodes (between c/20 and c/10 overcharge rates).

7. Internal Resistance.

8. Phenolphthalein Leak Test.

See Appendix I for detailed test procedure.

III. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers (3 through 11)--not consecutive.

B. The 100 ampere-hour cell is square with an average height, width and length of 8.273, 7.325 and 1.435 inches, respectively.

The average weight was 3694.2 grams. Individual measurements and averages are listed in Table I.

C. The cell containers and the cell covers are made of stainless steel. The positive and negative terminals were insulated from the cell covers by ceramic seals and protrude through the cover as solder type terminals. The auxiliary electrode terminal consists of a stainless steel tab welded to the cell cover. (See Photograph 1)

IV. RESULTS--The following data was condensed from Tables II through IV.

A. The average capacity for the three capacity checks was: 113.6 110.7 and 108.5 ampere-hours respectively. It should be noted that these cells were never charged (c/10 rate) beyond 13 hours due to high cell voltages.

B. The average recovery voltage was 1.222 volts.

C. End-of-Overcharge Voltage:

1. Cell voltages increased rapidly after 13 hours of charge at the c/10 rate. The current was therefore reduced stepwise to c/40 to remain below the 1.500 voltage limit. The cell voltages ranged from 1.458 to 1.499 volts under these conditions.

2. After the initial c/10 conditioning charge, reference (b) called for a c/20 charge for an additional 16 hours. This c/20 rate was never possible. The cells were maintained at the c/40 rate (established in the previous step) for 1 hour. Increasing cell voltages necessitated a further stepwise reduction of the overcharge current to c/125. The voltage ranged from 1.428 to 1.504 volts under these conditions.

3. No attempt was made to return to the c/10 rate or to maintain the overcharge at c/125 as previously established. This was in accordance with instructions from Goddard Space Flight Center.

D. Special Test for Determining the Resistance Giving Maximum Signal Power from the Auxiliary Electrode:

1. This test was conducted following the c/125 overcharge and prior to the c/10 overcharge (never performed) on two of the five cells. See Appendix I for details. Table IV shows 10 ohms as the resistance value giving the maximum power in millivolts across the auxiliary electrode.

E. Internal Resistance Averaged:

1. 1.3 milliohms across the cell terminals.

2. 5.6 milliohms across the auxiliary electrode.

F. Leak Tests:

1. One cell (S/N 3) revealed a definite leak at the negative terminal.

APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed prior to any other tests, with a phenolphthalein spray indicator solution of one-half of one percent concentration.

B. Capacity Tests:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks was made at this activity. The cells were discharged individually, but were recharged in series.

2. The auxiliary electrodes were without resistors until the resistance characterization was conducted during the overcharge tests following the c/20 rate and just prior to the c/10 rate. These tests precisely determined the correct resistance for the auxiliary electrode.

C. Cell Short Test

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each cell was loaded with a 0.05 ohm, 10 watt resistor for 16 hours. At the end of 16 hours, the shorting resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover the 1.150 volts or higher was considered as failing this portion of the acceptance test.

D. Leak Test

1. The leak test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence of leaks.

2. The cells were placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. The cells were then removed from the vacuum chamber and sprayed with phenolphthalein. Pink or redish discolorations would indicate leakage.

E. Overcharge Test

1. The purpose of this test is basically threefold:

a. To determine the degree to which a pack of cells maintain a balanced voltage.

b. To determine the cells capability of reaching a point of chemical equilibrium--oxygen recombination with the negtive (cadmium) plate.

c. To test the integrity of the seals as the pressure increases.

2. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/10, c/20 and c/10 for a minimum of 16 hours at each charge rate. The first c/10 rate serves to establish a condition of overcharge.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.500 volts or 100 psig.

4. The special resistance characterization tests for the auxiliary electrodes were conducted following the c/20 overcharge and prior to the c/10 overcharge. The cells were maintained on charge at c/125 throughout the special resistance test in order to maintain the voltage limit. The tests were conducted on the cells with pressure gauges and consisted of the following:

a. A decade resistance box was hooked across the auxiliary electrode of each cell (auxiliary electrode terminal to negative terminal) such that the resistance could be conveniently and precisely varied.

b. The pressure was maintained as close to ambient (0 psig) as possible throughout the test. No alteration of the c/125 charge rate was necessary for these cells to maintain this condition. The temperature was room ambient.

c. The sequence of resistance changes (ohms) were: 10,000, 5000, 2000;1000, 500, 200;100, 50, 20;10, 5, 2;1, 0.5, 0.2;and 0.1. A period of approximately 5 minutes was allowed for the equilibrium of the auxiliary electrode voltage to re-establish itself after each resistance change. This equilibrium was verified by observation of a strip chart recorder monitoring the auxiliary electrode voltage of each cell.

d. Data thus obtained was converted to power units in millivolts as illustrated at the foot of Table IV. The resistance value giving the maximum power of the auxiliary electrode signal is thus chosen for the auxiliary electrode resistance.

F. Internal Resistance;

1. Immediately following the overcharge test, the internal resistance was measured across the cell terminals and across the auxiliary electrodes (from auxiliary electrode terminal to negative terminal). These measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

G. Leak Test:

1. Following the internal resistance measurements, the cells were still in a charged state. The cells were discharged at c/2 to 0.00 volt and shorted prior to the final leak test. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph I.D.2. was repeated.

TABLE I

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	LEAK TESTS: Initial (Phenol Spray) Terminals +	Terminals -	Fill Tube	Other	After Capacity Tests (Hi Vac & Phenol Spray) Terminals +	Terminals -	Fill Tube	Other	After Overcharge Test (Hi Vac & Phenol Spray) Terminals +	Terminals -	Fill Tube	Other
3	3,670.0	8.272	1.440	7.318	O.K.	V.S.	O.K.	O.K.	O.K.	L	O.K.	O.K.	O.K.	V.S.	O.K.	O.K.
6	3,706.3	8.331	1.444	7.325	"	O.K.	"	"	"	O.K.	"	"	"	O.K.	"	"
8	3,712.7	8.255	1.434	7.340	"	"	"	"	"	"	"	"	"	"	"	"
10	3,693.2	8.252	1.430	7.320	"	"	"	"	"	"	"	"	"	"	"	"
11	3,688.6	8.254	1.425	7.322	"	"	"	"	"	"	"	"	"	"	"	"
Average	3,694.2	8.273	1.435	7.325												
	L = Leaker															
	V.S. = Very Slight															

QEEL/C 72-126

TABLE II
CAPACITY CHECK DATA

SERIAL NUMBER	FIRST CAPACITY CHECK: END-OF-CHARGE ** CELL (Volts)	AUX ELECT (Volts)	PRESS *	FIRST: END-OF-DISCHARGE CAPACITY (ah)	AUX ELECT (Volts)	PRESS *	SECOND CAPACITY CHECK: END-OF-CHARGE ** CELL (Volts)	AUX ELECT (Volts)	PRESS *	SECOND: END-OF-DISCHARGE CAPACITY (ah)	AUX ELECT (Volts)	PRESS *	THIRD CAPACITY CHECK: END-OF-CHARGE ** CELL (Volts)	AUX ELECT (Volts)	PRESS *	THIRD: END-OF-DISCHARGE CAPACITY (ah)	AUX ELECT (Volts)	PRESS *
3	1.500	0.839		114.0	0.540		1.500	0.835		113.5	0.650		1.503	0.938		111.5	0.657	
6	1.500	0.838	+14	106.0	0.586	+10	1.523	0.815	+15	103.5	0.654	+9	1.525	0.956	+17	105.0	0.638	+7
8	1.500	0.868	-20	117.5	0.675	-29	1.533	0.862	-20	114.0	0.660	-27	1.547	0.969	-7	109.0	0.656	-23
10	1.500	0.769		111.5	0.591		1.533	0.841		106.5	0.643		1.514	0.954		103.5	0.655	
11	1.500	0.865		119.0	0.652		1.500	0.922		116.0	0.657		1.500	0.952		113.5	0.654	
Average				113.6						110.7						108.5		
	** All cells reached the 1.500 voltage limit prior to the required 16 hours of charge at the c/10 rate. The times to 1.500 volts are noted below in hours and minutes.																	
3	11:34						12:59						13:20					
6	11:00						12:04						12:55					
8	11:55						12:55						12:55					
10	11:34						12:55						12:55					
11	11:53						13:02						13:20					

* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE III

SERIAL NUMBER	CELL SHORT TEST Recovery Voltage after 24 Hours (Volts)	END OF CHARGE VOLTAGE AT: c/10 CONDITIONING RATE			c/20 CONDITIONING RATE			c/10 CONDITIONING RATE			INTERNAL RESISTANCE MEASUREMENT (Milliohms)	
		* CELL (Volts)	AUX ELECT (Volts)	PRESS *	** CELL (Volts)	AUX ELECT (Volts)	PRESS *	*** CELL (Volts)	AUX ELECT (Volts)	PRESS *	CELL	AUX ELECT
3	1.223	1.443	0.898		1.428	0.875					1.3	7.6
6	1.228	1.462	0.908	+8	1.449	0.892	+1				1.6	4.9
8	1.210	1.499	0.923	+13	1.504	0.914	+6				1.3	4.4
10	1.224	1.458	0.909		1.442	0.892					1.2	5.9
11	1.224	1.477	0.932		1.481	0.924					1.1	5.2
Average	1.222										1.3	5.6

* Cell voltages increased rapidly after 13 hours of charge at the C/10 rate. The current was therefore reduced stepwise to C/40 to maintain the 1.500 voltage limit.

** The charge rate was maintained at C/40 for one hour. Increasing cell voltages necessitated a further stepwise reduction of the overcharge current to C/125.

*** Upon completion of the auxiliary electrode resistance characterization at the end of the "C/20" overcharge rate, the overcharge was terminated.

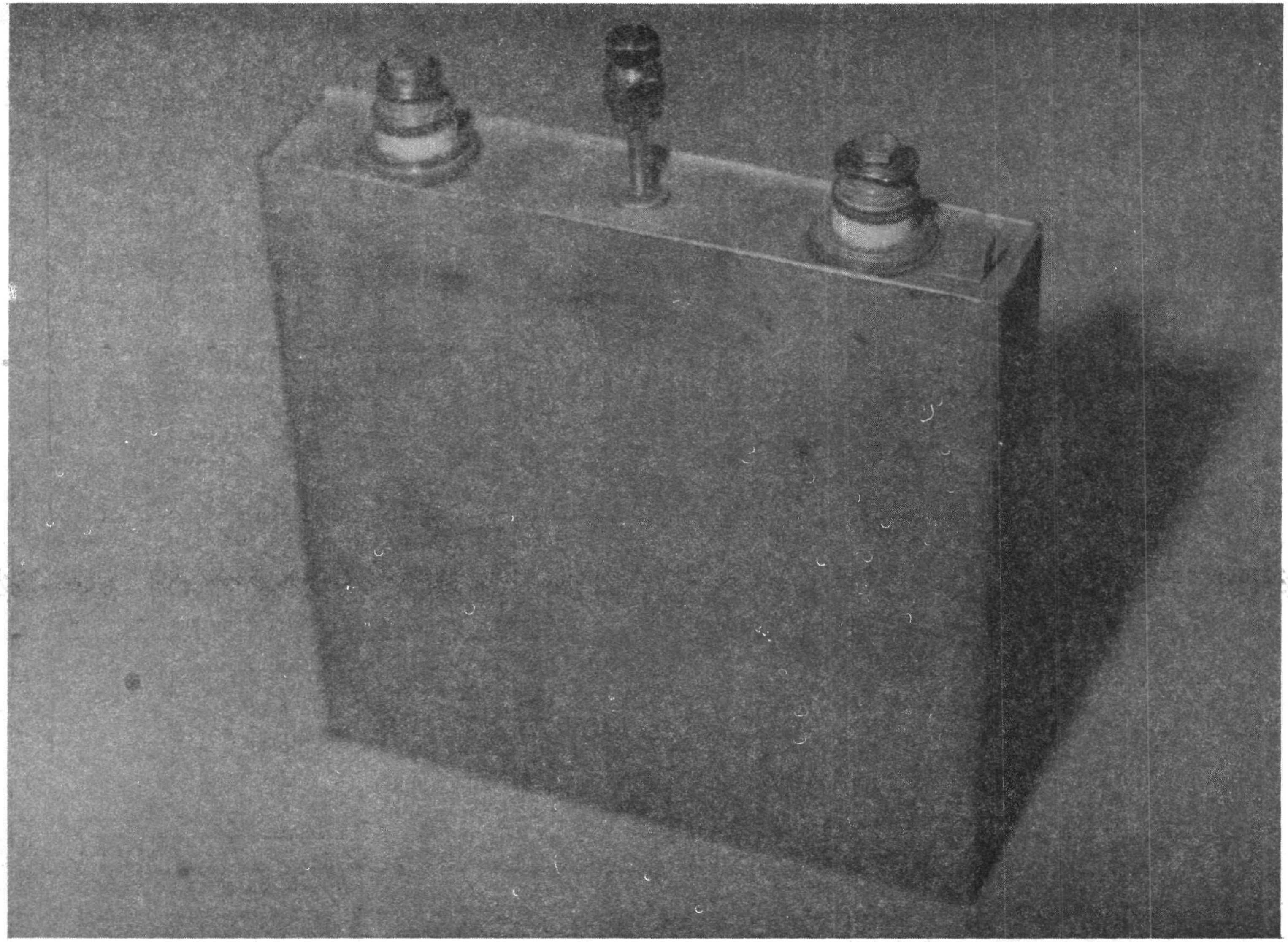
* Negative values are interpreted as inches of mercury vacuum, while positive values are psig.

TABLE IV
SPECIAL RESISTANCE TEST DATA ON THE AUXILIARY ELECTRODES

SERIAL NO.	6		8								AVERAGE	
OHMS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	PRESS	VOLTS	MILLIWATTS
10,000	0.817	+1	0.786	+5							0.802	0.064
5,000	0.772	..	0.715	..							0.744	0.111
2,000	0.689	..	0.635	..							0.662	0.219
1,000	0.607	..	0.568	..							0.588	0.346
500	0.528	..	0.504	..							0.516	0.533
200	0.423	..	0.390	..							0.407	0.828
100	0.333	..	0.297	..							0.315	0.992
50	0.250	..	0.230	+6							0.240	1.152
20	0.176	..	0.162	..							0.169	1.143
10	0.130	..	0.119	..							0.125	1.563 *
5	0.088	..	0.080	..							0.084	1.411
2	0.046	..	0.041	..							0.044	0.968
1	0.024	..	0.023	..							0.024	0.576
0.5	0.012	..	0.013	..							0.013	0.338
0.2	0.005	..	0.006	+7							0.006	0.180
0.1	0.003	..	0.004	..							0.004	0.160

* Maximum wattage across auxiliary electrode.

$$\text{POWER} = \frac{V^2}{R}\ \text{Watts}\quad 10^3\ \frac{\text{Milliwatts}}{\text{Watt}}\ :\ \text{Milliwatts}$$



DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
CRANE, INDIANA 47522

IN REPLY REFER TO:
3053-DEC:mm
8900

12 APR 1972

From: Commanding Officer, Naval Ammunition, Depot, Crane, Indiana
To: National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771

Subj: Report QEEL/C 72-126; Evaluation Program for Secondary Spacecraft Cells; Acceptance Tests of 100 Ampere-Hour Nickel-Cadmium Spacecraft Cells with Auxiliary Electrodes Manufactured by Eagle-Picher Company

Ref: (a) NASA P. O. S-23404-G

Encl: (1) Report QEEL/C 72-126

1. In compliance with reference (a), enclosure (1) is forwarded for information and retention.

H. L. Forston
H. L. FORSTON
By direction

Copy to:
Distribution List

National Aeronautics and Space Administration, Lewis Research Center (MS 309-1, Mr. Harvey Schwartz), 21000 Brookpark Road, Cleveland, Ohio 44135

National Aeronautics and Space Administration, Lewis Research Center (MS 309-1, Dr. J. Stuart Fordyce), 21000 Brookpark Road, Cleveland, Ohio 44135

National Aeronautics and Space Administration, George C. Marshall Space Flight Center (S&E-ASTR-EP, Mr. Charles B. Graff), Huntsville, Alabama 35812

National Aeronautics and Space Administration, Manned Spacecraft Center (EP-5, Mr. W. E. Rice), Houston, Texas 77058

National Aeronuatics and Space Administration, Ames Research Center (M.S. 244-2, PBS, Mr. Jon A. Rubenzer), Moffett Field, California 94035

Jet Propulsion Laboratory (M.S. 198-220, Mr. Daniel Runkle), 4800 Oak Grove Drive, Pasadena, California 91103

Jet Propulsion Laboratory (M.S. 198-220, Mr. Aiji Uchiyama), 4800 Oak Grove Drive, Pasadena, California 91103

Jet Propulsion Laboratory (M.S. 198-220, Dr. R. Lutwack), 4800 Oak Grove Drive, Pasadena, California 91103

Jet Propulsion Laboratory (Mr. R. S. Bogner), 4800 Oak Grove Drive, Pasadena, California 91103

Jet Propulsion Laboratory (M.S. 198-220, Mr. Stanley J. Krause), 4800 Oak Grove Drive, Pasadena, California 91103

Commanding General, U. S. Army Electro Technology Lab, Energy Conversion Research Division (MERDC), Fort Belvoir, Virginia 22060

Commanding General, U. S. Army Electronics R&D Labs (AMSEL-TL-P), Fort Monmouth, New Jersey 07703

Commanding General, U. S. Army Electronics Command (AMSEL-ME-NMP-TB-2, Mr. A. Frink), Fort Monmouth, New Jersey 07703

Harry Diamond Laboratories (Mr. Nathan Kaplan), Room 300, Building 92, Connecticut Ave. & Van Ness Street, N.W., Washington, D. C. 20438

DISTRIBUTION LIST

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 761.2, Mr. T. J. Hennigan), Greenbelt, Maryland 20771 (12 copies)

National Aeronautics and Space Administration (Code RPP, Mr. Ernst M. Cohn), Washington, D. C. 20546

National Aeronautics and Space Administration (Code SCC, Dr. A. M. Greg Andrus), Washington, D. C. 20546

National Aeronautics and Space Administration, Scientific and Technical Information Center; Input, P. O. Box 33, College Park, Maryland 20740 (3 copies)

National Aeronautics and Space Administration (Code UT, Dr. E. N. Case), Washington, D. C. 20546

National Aeroanutics and Space Administration (Code MTG, Mr. Richard Livingston), Washington, D. C. 20546

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 764 Mr. Gerald Halpert), Greenbelt, Maryland 20771

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 450, Mr. Louis Wilson), Greenbelt, Maryland 20771

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 761, Mr. William Webster), Greenbelt, Maryland 20771

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 761, Mr. Floyd Ford), Greenbelt, Maryland 20771

National Aeronautics and Space Administration, Goddard Space Flight Center (Code 761, Mr. Eugene R. Stroup), Greenbelt, Maryland 20771

National Aeroanutics and Space Administration, Langley Research Center (MS-472, Mr. John L. Patterson), Hampton, Virginia 23365

National Aeronautics and Space Administration, Langley Research Center (MS-488, Mr. Jack E. Zanks), Hampton, Virginia 23365

National Aeronautics and Space Administration, Lewis Research Center (MS 302-1, Dr. Louis Rosenblum), 21000 Brookpark Road, Cleveland, Ohio 44135

Air Force Cambridge Research Laboratory (LCC, Mr. Edward Raskind, Wing F), L. G. Hanscom Field, Bedford, Massachusetts 01731

Rome Air Development Center (Code TSGD, Mr. Frank J. Mollura), Griffiss Air Force Base, New York 13440

Headquarters, SAMSO (SMTAE, Lt. R. Ballard), Los Angeles Air Force Station, Los Angeles, California 90045

National Science Foundation (Dr. Jesse C. Denton), 1800 G Street, N.W., Washington, D. C. 20550

Director, Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314 (20 copies)

Defence Research Establishment, Power Sources Division (Dr. Tom King), Shirley Bay, Ottawa, Ontario, Canada

Defence Research Establishment, Power Sources Division (Dr. Joseph Lackner), Shirley Bay, Ottawa, Ontario, Canada

Telesat Canada (Dr. M. A. Stott), 333 River Road, Ottawa, Ontario, Canada

Aerospace Corporation (Library Acquisition Group), P. O. Box 95085, Los Angeles, California 90045

Aerospace Corporation (Mr. Larry Gibson), P. O. Box 95085, Los Angeles, California 90045

American Cyanamid Company (Dr. R. A. Haldeman), 1937 W. Main Street, Stamford, Connecticut 06902

AMF, Inc. (Mr. R. A. Knight), 689 Hope Street, Stamford, Connecticut 06906

American University, Chemistry Department (Dr. R. T. Foley), Massachusetts & Nebraska Avenues, N. W., Washington, D. C. 20016

Artech, Inc. (Dr. Frank Swindell), 2816 Fallfax Drive, Falls Church, Virginia 22042

Atomics International Division, North American Aviation, Inc. (Dr. H. L. Recht), P. O. Box 309, Canoga Park, California 91304

Autonetics Division, NAR (Mr. R. F. Fogle, GF 18), P. O. Box 4181, Anaheim, California 92803

Harry Diamond Laboratories, Room 300, Building 92, Connecticut Ave. & Van Ness Street, N.W., Washington, D. C. 20438

Chief of Naval Research (Code 473, Director, Power Program), Department of the Navy, Arlington, Virginia 22217

Chief of Naval Research (Code 472, Mr. Harry Fox), Department of the Navy, Arlington, Virginia 22217

Director, Naval Research Laboratory (Code 6160, Mr. S. Schuldiner), 4555 Overlook Avenue, S.W., Washington, D. C. 20360

Director, Naval Research Laboratory (Code 7975, Mr. Joe Yuen), 4555 Overlook Avenue, S.W., Washington, D. C. 20360

Officer In Charge, Annapolis Division, Naval Ship Research & Development Center (Code A731, Mr. J. H. Harrison), Annapolis, Maryland 21402

Commander, Naval Air Systems Command (AIR-310C, Dr. H. Rosenwasser), Department of the Navy, Washington, D. C. 20360

Commander, Naval Air Systems Command (AIR-53643, Mr. E. White), Department of the Navy, Washington, D. C. 20360

Commander, Naval Ordnance Laboratory, White Oak (Code 232, Mr. Philip B. Cole), Silver Spring, Maryland 20910

Commander, Mare Island Naval Shipyard (Code 134.1, Chemical Laboratory), Vallejo, California 94592

Commander, Naval Ship Engineering Center (Code 61570, Mr. Albert Himy), Center Building, Prince George Center, Hyattsville, Maryland 20782

Superintendent, Naval Observatory (STIC, Mr. Robert E. Trumbule), 4301 Suitland Road, Suitland, Maryland 20390

Commander, Naval Ship Systems Command (SHIP-03422, Mr. Bernard B. Rosenbaum), Department of the Navy, Washington, D. C. 20360

Commander, AFAPL (POE-1, Mr. D. Pickett), Wright-Patterson Air Force Base, Ohio 45433

Commander, AFAPL (POE-1, Mr. R. L. Kerr), Wright-Patterson Air Force Base, Ohio 45433

Delco-Remy Division, General Motors Corporation (Mr. J. A. Keralla), 2401 Columbus Avenue, Anderson, Indiana 46011

Eagle-Picher Industries, Inc., Couples Department (Mr. E. P. Broglio), P. O. Box 47, Joplin, Missouri 64801

E. I. du Pont DeNemours & Company, Engineering Materials Laboratory, Experimental Station, Bldg 304 (Mr. J. M. Williams), Wilmington, Delaware 19898

ESB, Inc. (Director of Engineering), P. O. Box 11097, Raleigh, North Carolina 27604

ESB, Inc., Carl F. Norberg Research Center (Dr. A. J. Salkind), 19 West College Avenue, Yardley, Pennsylvania 19067

Electrochimica Corporation (Dr. Morris Eisenberg), 1140 O'Brien Drive, Menlo Park, California 94025

Electromite Corporation (Mr. R. H. Sparks), 2117 South Anne Street, Santa Ana, California 92704

Elpower Corporation (Mr. V. L. Best), 2117 South Anne Street, Santa Ana, California 92704

Emhart Corporation (Dr. W. P. Cadogan), Box 1620, Hartford, Connecticut 06102

Energetics Science, Inc. (Dr. H. G. Oswin), 4461 Bronx Boulevard, New York, New York 10470

Energy Research Corporation (Mr. Martin Klein), 15 Durant Avenue, Bethel, Connecticut 06801

Fairchild Industries, Inc., ATS Power Laboratory (Mr. Fred E. Betz), Germantown, Maryland 20767

Federal City College (Dr. M. Savitz), 425 Second Street, N.W., Washington, D. C. 20001

Dr. Arthur Fleischer, 466 South Center Street, Orange, New Jersey 07050

General Dynamics/Corvair (Dept. 967-50, Mr. R. P. Mikkelson), San Diego, California 92112

Battelle Memorial Institute (Dr. John McCallum), 505 King Avenue, Columbus, Ohio 43201

Bellcom, Inc. (Mr. J. J. Sakolosky), 955 L'Enfant Plaza, North, S.W., Washington, D. C. 20024

Bellcom, Inc. (Mr. W. W. Hough), 955 L'Enfant Plaza, North, S.W., Washington, D. C. 20024

Bell Telephone Labs, Inc. (Mr. D. O. Feder), Murray Hill, New Jersey 07974

Bell Telephone Laboratories (Mr. R. L. Beauchamp), Murray Hill, New Jersey 07974

Dr. Carl Berger, 13401 Kootenay Drive, Santa Ana, California 92705

The Boeing Company (MS 84-79, Mr. Sidney Gross), P. O. Box 3999, Seattle, Washington 98124

Burgess Battery Division, Gould, Inc. (Mr. M. E. Wilke, Chief Engineer), Freeport, Illinois 61032

C & D Batteries, Division of Electric Autolite Co. (Dr. Eugere Willihnganz), 3043 Walton Road, Plymouth Meeting, Pennsylvania 19462

Calvin College (Prof. T. P. Dirkse), 3175 Burton Street, S. E., Grand Rapids, Michigan 49506

Catalyst Research Corporation (Mr. F. Tepper), 6101 Falls Road, Baltimore, Maryland 21209

Ceramaseal, Inc. (Mr. Robert Turner), New Lebanon Center, New York 12126

Chrysler Corporation, Space Division (Mr. C. E. Thomas), P. O. Box 29200, New Orleans, Louisana 70129

Communications Satellite Corp., Comsat Laboratories (Mr. Robert Strauss), P. O. Box 115, Clarksburg, Maryland 20734

G. & W. H. Corson, Inc. (Dr. L. J. Minnich), Plymouth Meeting, Pennsylvania 19462

Cubic Corporation (Librarian), 9233 Balboa Avenue, San Diego, California 92123

Gulton Industries, Battery & Power Sources Division, 212 Durham Avenue, Metuchen, New Jersey 08840

Gulton Industries (Mr. Ed Kantner), 212 Durham Avenue, Metuchen, New Jersey 08840

Hercules, Inc. (Mr. Paul Cox), P. O. Box 12145, Research Triangle Park, North Carolina 27709

Honeywell, Inc., Livingston Electronic Laboratory (Librarian), Montgomeryville, Pennsylvania 18936

Dr. P. L. Howard, Centreville, Maryland 21617

Hughes Aircraft Corporation (M.S. 524, Bldg. 366, Mr. M. E. Ellion), El Segundo, California 90245

ITT Research Institute (Dr. H. T. Francis), 10 West 35th Street, Chicago, Illinois 60616

Idaho State University, Department of Chemistry (Dr. G. Myron Arcand), Pocatello, Idaho 83201

University of Illinois (306E Talbot Laboratory, Prof. Will J. Worley), Urbana, Illinois 61801

Institute for Defense Analyses (Mr. R. Hamilton), 400 Army-Navy Drive, Arlington, Virginia 22202

Institute for Defense Analyses (Dr. R. Briceland), 400 Army-Navy Drive, Arlington, Virginia 22202

International Nickel Company (Mr. N. A. Matthews), 1000-16th Street, N.W., Washington, D. C. 20036

Johns Hopkins University, Applied Physics Laboratory (Mr. Richard E. Evans), 8621 Georgia Avenue, Silver Spring, Maryland 20910

Leesona Moos Laboratories (Dr. A. Moos), Lake Success Park, Community Drive, Great Neck, New York 11021

Life Systems, Inc. (Dr. Richard A. Wynveen, Pres.), 23715 Mercantile Road, Cleveland, Ohio 44122

Arthur D. Little, Inc. (Dr. James D. Birkett), Acorn Park, Cambridge, Massachusetts 02140

General Electric Company, Research and Development Center (Dr. R. P. Hamlen), P. O. Box 43, Schenectady, New York 12301

General Electric Company, Research and Development Labs (Dr. F. Will), Schenectady, New York 12301

General Electric Company, Research and Development Labs (Dr. J. L. Weininger), Schenectady, New York 12301

General Electric Company, Space Systems (Mr. K. L. Hanson, Room M-2700), P. O. Box 8555, Philadelphia, Pennsylvania 19101

General Electric Company, Space Systems (Mr. Aaron Kirpich, Room M-2614), P. O. Box 8555, Philadelphia, Pennsylvania 19101

General Electric Company, Missile and Space Division (Mr. H. Thierfelder), P. O. Box 8555, Philadelphia, Pennsylvania 19101

General Electric Company, Battery Business Section (Mr. P. R. Voyentzie), P. O. Box 114, Gainesville, Florida 32601

General Electric Corporation (Mr. Guy Rampel), Gainesville, Florida 32601

General Electric Company (Whitney Library), P. O. Box 8, Schenectady, New York 12301

General Electric Company (Mr. David F. Schmidt), 777-14th Street, N.W., Washington, D. C. 20005

Globe-Union, Inc. (Dr. R. Goodman), P. O. Box 591, Milwaukee, Wisconsin 53201

Globe-Union, Inc. (Dr. Eugene Wissman), P. O. Box 591, Milwaukee, Wisconsin 53201

Gould Ionics, Inc. (Dr. J. E. Oxley), P. O. Box 1377, Canoga Park, California 91304

Gould, Inc. (Dr. C. J. Menard), 2630 University Avenue, S.E., Minneapolis, Minnesota 55414

Grumman Aerospace Corporation (Plant 35, Dept 567, Mr. Steve J. Gaston), Bethpage, Long Island, New York 11714

RAI Research Corporation, 225 Marcus Boulevard, Hauppauge, New York 11787

RCA Corporation, Astro Electronics Division (Mr. Paul Nekrasov), P. O. Box 800, Princeton, New Jersey 08540

SAFT Corporation of America (Mr. D. Verrier), 50 Rockefeller Plaza, New York, New York 10020

Mr. Joseph M. Sherfey, 5261 Nautilus Drive, Cape Coral, Florida 33904

Southwest Research Institute (Library), P. O. Drawer 28510, San Antonio, Texas 78228

Spectrolab, Inc. (Dr. Harvey Seiger), 12484 Gladstone Avenue, Sylmar, California 91342

Stanford Research Institute (Dr. Fritz R. Kalhammer), 19722 Jamboree Boulevard, Irvine, California 92664

Texas Instruments, Inc. (Dr. J. W. Ross), 34 Forest Street, Attleboro, Massachusetts 02703

TRW Systems, Inc. (Dr. W. R. Scott, M-2/2154), One Space Park, Redondo Beach, California 90278

TRW Systems, Inc. (Dr. Herbert P. Silverman, R-1/2094), One Space Park, Redondo Beach, California 90278

TRW, Inc. (Librarian, TIM 3417), 23555 Euclid Avenue, Cleveland, Ohio 44117

Tyco Laboratories, Inc. (Dr. Jose Giner), Bear Hill, Hickory Drive, Waltham, Massachusetts 02154

Tyco Laboratories, Inc. (Mr. Edward J. Rubin), 16 Hickory Drive, Waltham, Massachusetts 02154

Union Carbide Corporation, Development Laboratory, P. O. Box 6056, Cleveland, Ohio 44101

Union Carbide Corporation, Consumer Products Division, (Dr. Ralph Brodd), P. O. Box 6116, Cleveland, Ohio 44101

Union Carbide Corporation, Consumer Products Division (Dr. Robert Powers), P. O. Box 6116, Cleveland, Ohio 44101

Lockheed Aircraft Corporation (Bldg. 157, Dept. 62-25, Mr. Robert E. Corbett), P. O. Box 504, Sunnyvale, California 94088

Lockheed Aircraft Corporation (Bldg. 151, Dept. 62-25, Mr. M. G. Gandel), P. O. Box 504, Sunnuvale, California 94088

Mallory Battery Company (Mr. R. R. Clune), So. Broadway and Sunnyside Lane, Tarrytown, New York 10591

Mallory Battery Company (Mr. S. J. Angelovich, Chief Engineer), So. Broadway, Tarrytown, New York 10591

P. R. Mallory and Co., Inc. (Dr. Per Bro), Northwest Industrial Park, Burlington, Massachusetts 01801

P. R. Mallory and Co., Inc. (Library), P. O. Box 1115, Indianapolis, Indiana 46206

Marathon Battery Company (Mr. Lou Belove), P. O. Box 8233, Waco, Texas 76710

Martin-Marietta Corporation (M.S. 1620, Mr. William B. Collins & M.S. F8845, Mr. M. S. Imamura), P. O. Box 179, Denver, Colorado 80201

McDonnell Douglas Astronautics Company (Bldg 22-A3-830, MS 17, Mr. A. D. Tonelli), 5301 Bolsa Avenue, Huntington Beach, California 92647

McDonnell Douglas Astronuatics Company, Headquarters Space Systems Center (Bldg 11-3-12, MS 12, Dr. George Moe), 5301 Bolsa Avenue, Huntington Beach, California 92647

Motorola, Inc. (Dr. Robert C. Shair), 8000 West Sunrise Boulevard, Ft. Lauderdale, Florida 33313

North American Rockwell Corp., Rocketdyne Division (Library), 6633 Canoga Avenue, Canoga Park, California 91304

Philco-Ford Corporation, Power and Control Engineering Department (M.S. R-26, Mr. D. C. Briggs), 3939 Fabian Way, Palo Alto, California 94303

Portable Power Sources Corporation (Mr. Leon Schulman), 166 Pennsylvania Avenue, Mt. Vernon, New York 10552

Power Information Center, University City Science Institute, Room 2210, 3401 Market Street, Philadelphia, Pennsylvania 19104

University of Pennsylvania, Electrochemistry Laboratory (Prof. John O'M. Bockris), Philadelphia, Pennsylvania 19104

Utah Research and Development Co., Inc. (Mr. William Boyd), 1820 South Industrial Road, Salt Lake City, Utah 84104

Westinghouse Electric Corporation, Research and Development Center (Dr. C. C. Hein, Contract Admin.), Churchill Borough, Pittsburg, Pennsylvania 15235

Whittaker Corporation, Power Sources Division, 3850 Olive Street, Denver, Colorado 80207

Yardney Electric Co. (Mr. P. Deluca and Mr. M. Read), 82 Mechanic Street, Pawcatuck, Connecticut 02891